LASER MODULATION AT THE ATOMIC LEVEL

Monthly Report No. 5

Date of this report: 10 December 1964
Period covered: 1 November 1964 to 30 November 1964

Submitted to
National Aeronautics and Space Administration
Contract No. NASw 1008

GENERAL DYNAMICS | ELECTRONICS

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LASER MODULATION AT THE ATOMIC LEVEL

Purpose

Research on methods of influencing internally the radiating centers of active laser materials in order to achieve laser modulation is the principal objective of the work carried out under this contract.

Summary

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Population inversion as a function of peak magnetic field was measured for a 90° ruby rod. Unlike the 0° rod, minimum inversion coincides with zero magnetic field, and the slope of threshold population inversion versus magnetic field is more than an order of magnitude higher in the high field region for the 90° rod.

The YAG:Nd^{3+} laser rod was not returned by Linde in time for the experiments to be continued during this reporting period. Rough estimates of the Zeeman splitting to be expected from the lines involved in laser emission at room temperature and at liquid nitrogen temperature have been made. If the crystal field terms in the Zeeman splitting calculation are ignored, each of these lines should split into four components in a magnetic field, the splitting for the room temperature line being approximately four times that of the low temperature line.

AUTHOR

Man-Hours Worked

The total number of man-hours worked during the reporting period is 420.

I. STUDY OF RUBY

A. Excited State Absorption Spectra

The assumption made in Monthly Reports Nos. 3 and 4 that there was an error in the graph of $\sigma_\omega{}^*$ presented by Gires and Mayer was not borne out by an examination of their previously published[1] data on a 0° rod. Some further checks for systematic errors in our measuring techniques were made, using Corning glass color filters in front of the probe signal photomultiplier to increase rejection of undesired wavelengths. The filters served to reduce pickup of scattered laser light, but the ratios of pumped intensity to unpumped intensity were not affected. Although this discrepancy in $\sigma_\omega{}^*$ is perplexing, the excellent agreement in the region 4000 to 5000 A would imply that our measurement of population using transmission at 4100 A is probably valid.

B. Threshold Population Inversion; 90° Ruby

Measurement of threshold population inversion in the 90° ruby rod (ruby #6) involved modification of the apparatus only by insertion of a Nicol prism to select the ordinary ray ($E \perp c$) for transmission measurements. The ground state absorption cross section for the extraordinary ray ($E \parallel c$) is about twice as large as for the ordinary ray ($E \perp c$) at 4100 A, making it easy to set the polarizing prism for transmission of the ordinary ray.

The reduction in gain by the magnetic field is so much more pronounced for the 90° ruby that only relatively low values of magnetic field could be used before the capabilities of our pump lamp were exceeded. Since the pumping above the zero field saturation level must take place during the quarter period between initiation of the field pulse and its first peak, the field delay was adjusted to have the first quarter period coincide with the maximum pump intensity. The maximum value of peak field for which threshold could be achieved was 5.5 kgauss. The results of experiments on both the 0° ruby and the 90° ruby at 115°K are shown in Fig. 1. The slope of the population inversion versus magnetic field for the 90° ruby is about a factor of 60 higher than that for the 0° ruby in the almost linear "high field" region of the curves.

II. ZEEMAN SPLITTING IN YAG:Nd^{3+} EMISSION LINES

The YAG:Nd^{3+} laser rod was not returned by Linde in time for continuation of experimental work in this reporting period. In order to get an

1. F. Gires and G. Mayer, Compt. Rend., 254, 659 (1962).

approximate value for the Zeeman splitting to be expected from the fluorescent lines involved in laser emission, g values were calculated neglecting crystal field terms. Spectral assignments were taken from the paper of Geusic, Marcos, and Van Uitert[2] with the additional assumption that the levels in both the $^4F_{3/2}$ and $^4I_{11/2}$ terms are ordered with the higher M values having higher energy. Under these assumptions the transition reported to be responsible for laser oscillation at room temperature is from the M = ±3/2 level of the $^4F_{3/2}$ term to the M = ± 5/2 level of the $^4I_{11/2}$ term, whereas the one responsible for laser oscillation at 77°K originates at the M = ±1/2 level of the $^4F_{3/2}$ term and terminates at the M = ±1/2 level of the $^4I_{11/2}$ term. These transitions are shown in Fig. 2, which is taken from the paper by Geusic et. al.[2] The free ion g values for the two terms are:

Term	g
$^4F_{3/2}$	0.400
$^4I_{11/2}$	0.965

The Zeeman shifts in the line components in the free ion approximation are simply given by $\Delta\nu = (g_1 M_1 - g_2 M_2)\beta H$, where 1 refers to the upper state and 2 to the lower state. The predicted Zeeman splitting for the two laser transitions based on these assumptions is shown in Fig. 3. It will be noted that the splitting is about four times greater for the room temperature laser transition than for the low temperature one. The primary purpose of these calculations is to give an order of magnitude estimate of the frequency shifts to be anticipated in the pulsed homogeneous field experiments with YAG:Nd^{3+} laser.

2. J. E. Geusic, H. M. Marcos, and L. G. Van Uitert, Appl. Phys. Letters, 4, 182 (1964).

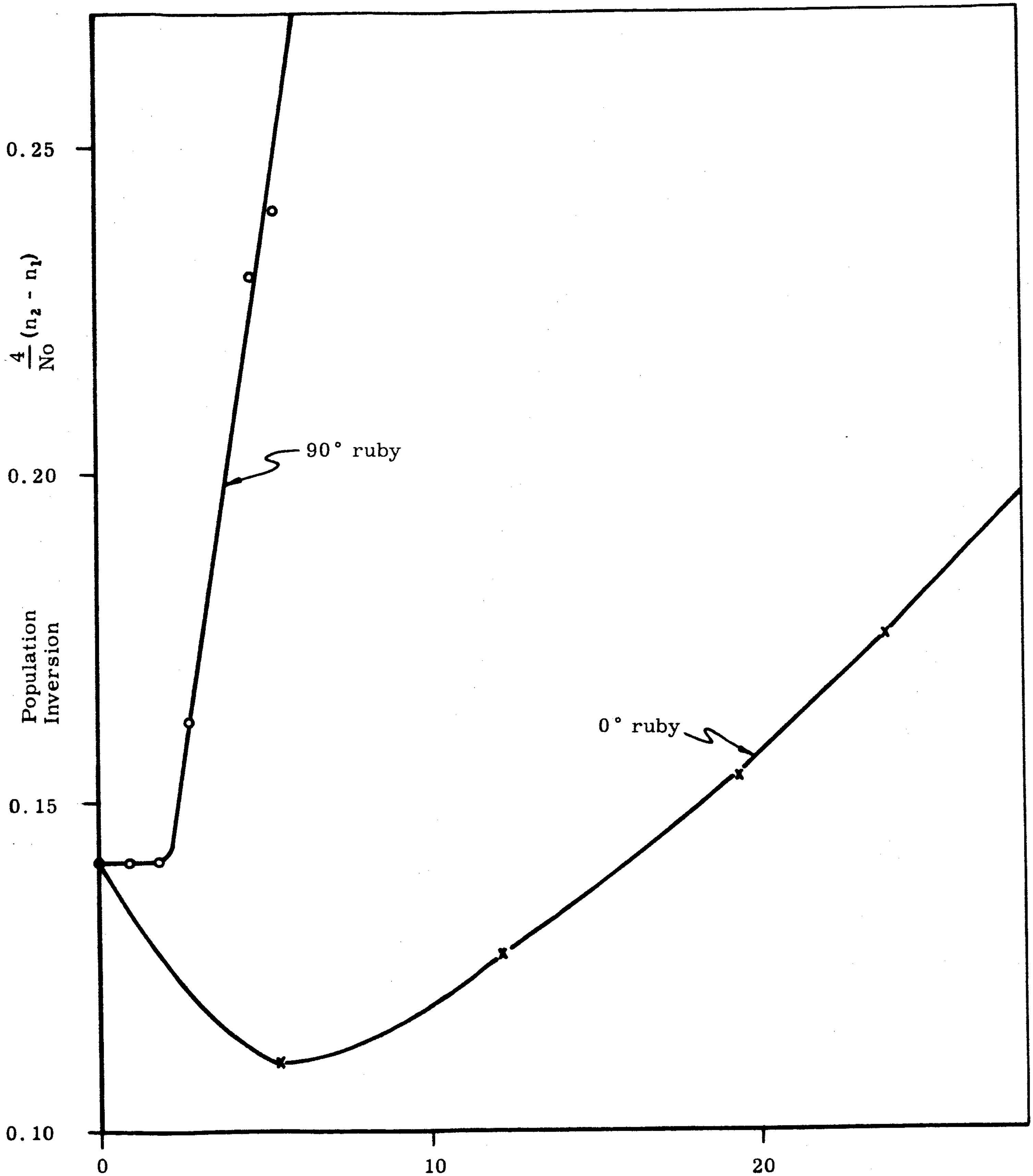

Fig. 1. Population inversion at laser threshold as a function of peak magnetic field at 115°K.

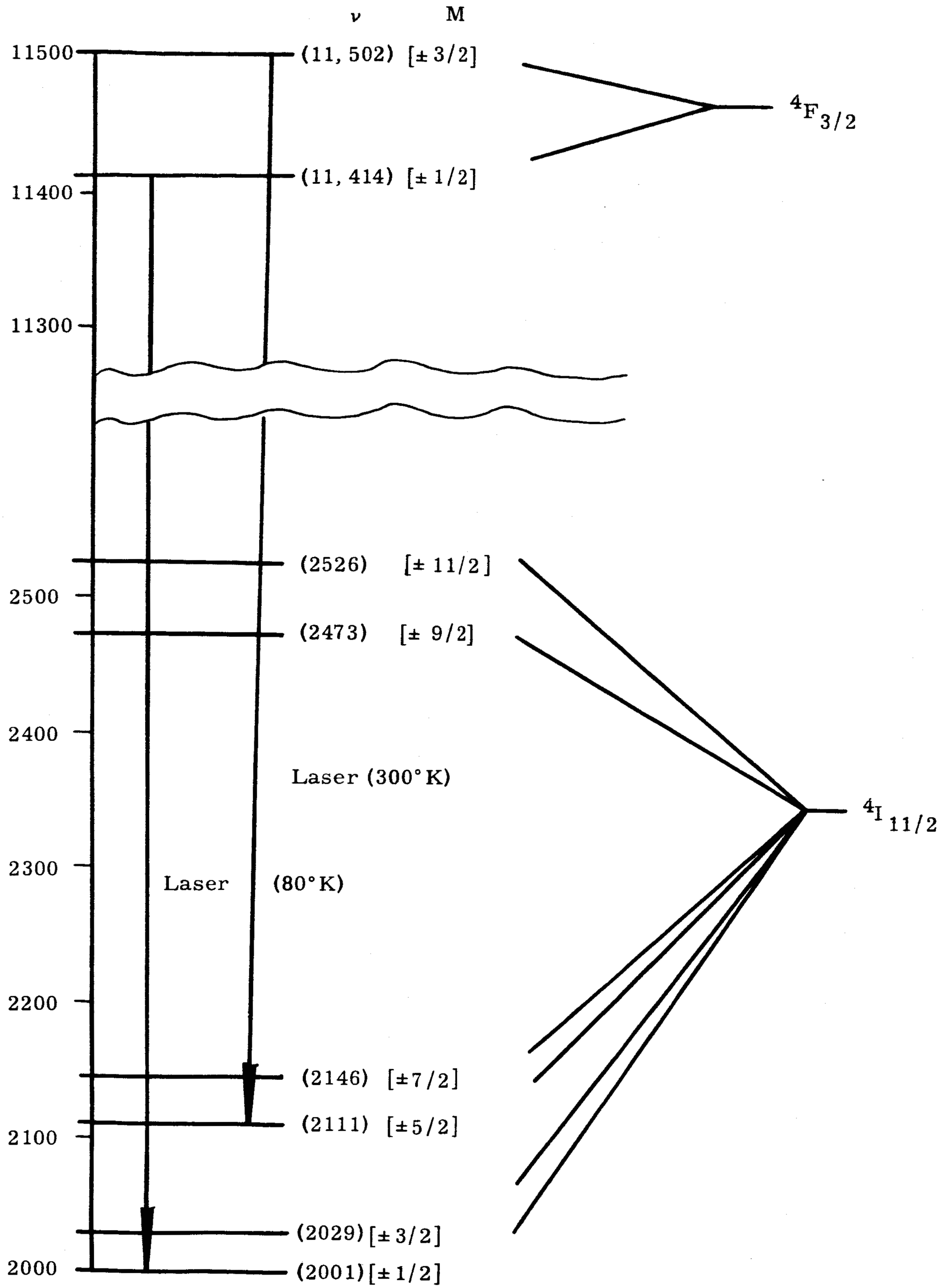

Fig. 2. Energy levels of Nd^{3+} in YAG according to Geusic, etal.

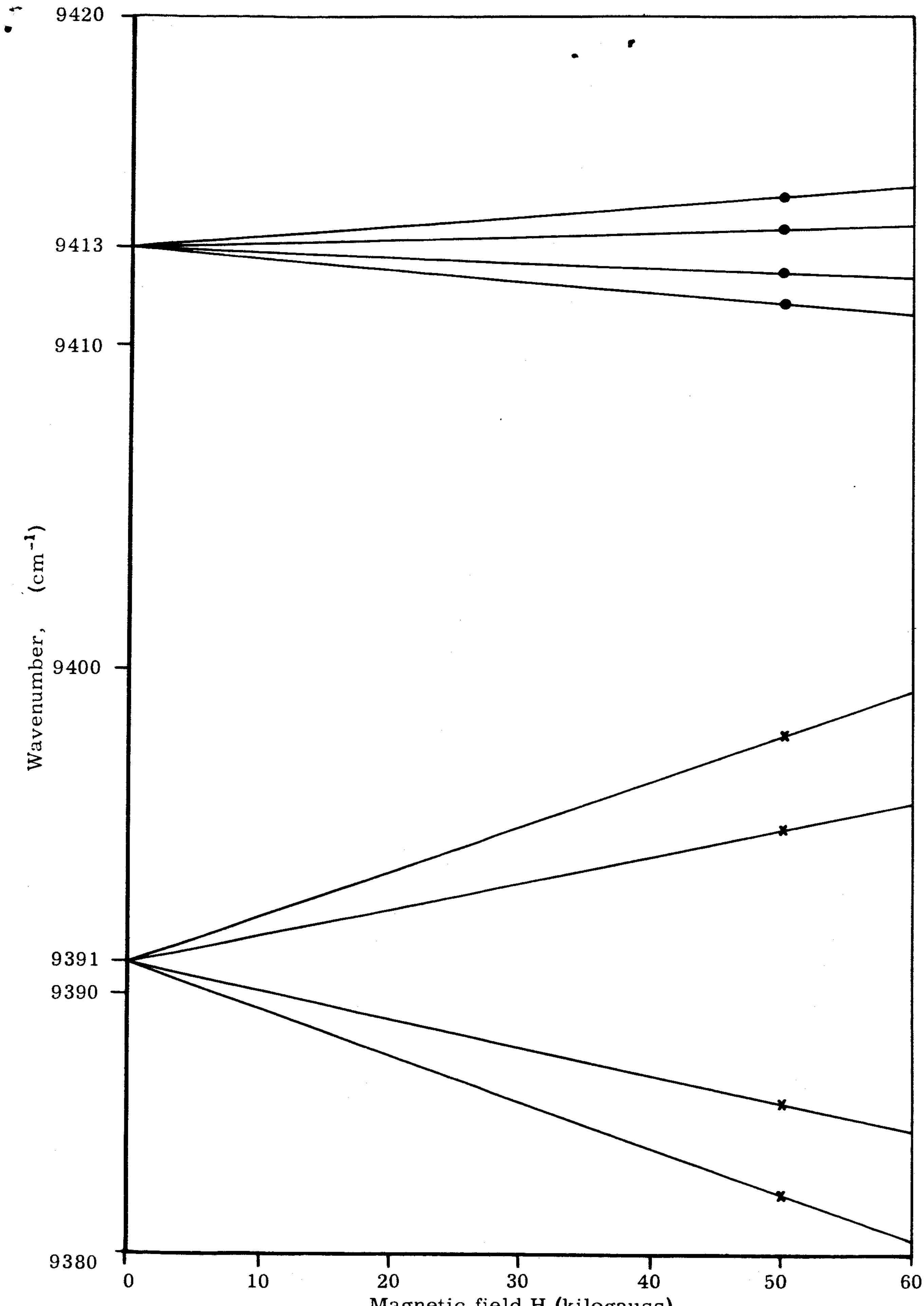

Fig. 3. Calculated Zeeman splitting in YAG: Nd^{3+} using free ion Lande factors for transitions of interest in laser operation.